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EDGEWOOD CHEMICAL BIOLOGICAL CENTER

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND
Aberdeen Proving Ground, MD 21010-5424

ECBC-TR-1371

UNMANNED AERIAL VEHICLE NON-LINE-OF-SIGHT CHEMICAL DETECTION FINAL REPORT

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December 2016

Approved for public release; distribution unlimited.

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The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorizing documents.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
XX-12-2016

2. REPORT TYPE
Final

3. DATES COVERED *(From - To)*
Mar 2015 – Dec 2015

4. TITLE AND SUBTITLE
Unmanned Aerial Vehicle Non-Line-of-Sight Chemical Detection Final Report

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Colgan, Mark A.

5d. PROJECT NUMBER
ECBC Section 219 IPP FY15

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Director, ECBC, ATTN: RDCB-DEE-E, APG, MD 21010-5424

8. PERFORMING ORGANIZATION REPORT NUMBER
ECBC-TR-1371

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Edgewood Chemical Biological Center

10. SPONSOR/MONITOR'S ACRONYM(S)
ECBC

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT:
This study describes the development and demonstration of a quadcopter unmanned aircraft system that is used to perform point detection of chemical warfare agents and collection of vapor, liquid, and solid samples. A modular payload system was developed, and prototypes of several modules were fabricated. Capability demonstrations of the payload system and prototypes, without direct visibility (non-line-of-sight), were conducted.

15. SUBJECT TERMS

Non-line-of-sight	Point detector	Chemical detection	Sample collection
Standoff	Quadcopter	Unmanned aircraft system	Modular payload

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Renu B. Rastogi
					19b. TELEPHONE NUMBER *(include area code)*
U	U	U	UU	18	(410) 436-7545

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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PREFACE

The work described in this report was authorized by the U.S. Army Edgewood Chemical Biological Center (ECBC) as a Section 219 Innovative Proposal Program for fiscal year 2015. The work was started in March 2015 and completed in December 2015.

The use of either trade or manufacturers' names in this report does not constitute an official endorsement of any commercial products. This report may not be cited for purposes of advertisement.

This report has been approved for public release.

Acknowledgments

The authors acknowledge the following individuals for their hard work and assistance with the execution of this technical program:

- Kyle Ford, Corey Piepenburg, and John Sparks (ECBC) for their support; and
- Harold Wylie (TriMech Solutions, LLC, Columbia, MD) for unmanned aircraft system interfacing, design, and test support.

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UNMANNED AERIAL VEHICLE NON-LINE-OF-SIGHT CHEMICAL DETECTION FINAL REPORT

1. INTRODUCTION

Department of Defense members with missions to detect and sense chemical, biological, radiological, nuclear, and explosive (CBRNE) hazards are investigating alternative means to achieve their goals to better protect the Warfighter. The North Atlantic Treaty Organization members have divided detection distances into the following three classes:

- point (closer than 10 cm),
- proximal (between 10 cm and 200 m), and
- standoff (further than 200 m).

In accordance with the inverse-squared law, the use of standoff laser spectroscopy systems for remote detection is hindered by the fact that laser intensity decreases in inverse proportion to the square of the distance. In addition, atmospheric interferents, such as water vapor and dust particles, can hinder laser techniques by absorbing certain wavelengths of light and act as scattering sites, thereby further decreasing incoming signal intensity. Currently, the Warfighter must have a direct line-of-sight with the substance in question; that is, there cannot be solid objects between the Warfighter and the material in question, nor can there be a change in direction in the detection method. An innovative approach must be taken to collect information on potential hazards beyond the Warfighter's line-of-sight to retain the integrity of the signal or sample for analysis.

2. PRODUCT DEVELOPMENT

2.1 Background

Current detection methods are limited in their ability to perform at standoff distances. One method to detect materials at proximal and standoff distances includes the use of laser technology. Laser systems require exponentially increasing power to perform at greater distances; they can only operate within direct line-of-sight, and they pose hazards to unprotected skin and eyes. A second method is the use of robotics on the ground to detect CBRNE hazards. Ground-based robotic systems require transportation to deploy the equipment to the area of concern; large obstacles and rough topographical terrain pose additional challenges. An unmanned aircraft system (UAS) can overcome these obstacles by flying close to unknown materials for onboard analysis or transporting chemical samples for analysis to a mobile laboratory.

An innovative proposed solution to non-line-of-sight standoff detection is to re-conceptualize remote detection by combining the best attributes of point, proximal, and standoff detection into a single scheme. Specifically, threat samples must be analyzed using point or proximal detectors, such as samplers mounted on UAS platforms, which are operated at

standoff distances from the human analyst. This design combines the detection and sampling of infield hazards at point and proximal distances, with the reduced risk to the human user typically associated with point detection. The utmost accuracy of sample or data collection is ensured because no signal is lost over distances, and the risk is minimized by operating the UAS at standoff distances using wireless controls and communication. Any direct threat to the user is minimized, and a high-quality sample can be collected for follow-on confirmatory analysis.

2.2 Technical Objectives

Leveraging UAS platforms in development by the U.S. Army Edgewood Chemical Biological Center (ECBC) Advanced Design and Manufacturing Division, modular payloads are being developed to perform point detection and CBRNE sampling. The available UAS is a quadcopter capable of precision drops that is operated by auto-pilot to land within 12 in. of a target, using a vertical takeoff and landing (VTOL) approach. The UAS is also able to be remotely flown with a video-game-like controller. The UAS is modular in nature (i.e., parts can be replaced as they wear out or as advancements are made), and it can carry a 5–7 lb payload with 15–25 min of flight time, permitting a range of a few kilometers. In addition, the vehicle is able to drop off a sensor and collect a sample within that range. A sampling module has been designed to fit the current UAS payload interface and has been demonstrated in the collection of powdered samples.

For this project, the initial UAS payload was a chemical sampling device. A number of sampling approaches, including the use of sticky tapes for solid samples and absorptive polymer pads for liquid samples, are being investigated. The initial demonstration included flight of the UAS to a prepositioned target beyond the line-of-sight of the UAS operator. The onboard camera and controller were used to bring the UAS to the target, which contained gram quantities of nontoxic liquid and solid materials. In one test, the UAS was made to hover over the target to investigate the ability of its prop wash to transfer solids from the target to the onboard sampler. In a second series of tests, the camera and controller were used to make the UAS hover over the target with minimal lift to provide nominal contact with the target for liquid sample collection. After each collection test, the UAS was returned to the operator. Initial analytical interrogation of the sampling materials relied on techniques for locally available devices because of the minimal need for sample preparation.

3. SYSTEM DESIGN

3.1 Unmanned Aircraft System

Modifications were made to an existing UAS to support the additional payload mounting. The existing payload transport and emplacement carriage design was used to provide quick attach and release between the UAS and the sensing and sampling payload modules. Figure 1 shows a bottom view of the updated UAS with the attached solid sample collection payload.

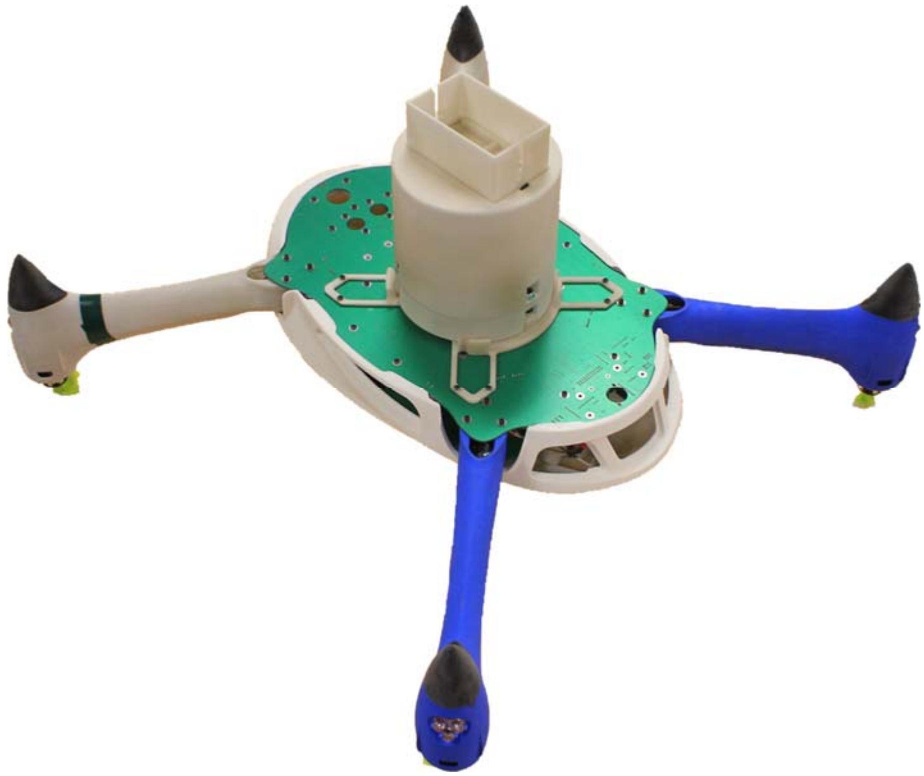

Figure 1. Unmanned aircraft system with payload (inverted).

3.2 Sample Collection System

A physical sample collection system using an adhesive tape was designed using the three-dimensional (3D) computer-aided design (CAD) modeling software Solidworks 3D CAD (Waltham, MA). A physical collection device was fabricated using additive manufacturing (i.e., 3D printing) techniques. This design is shown in Figure 2, and it includes a spring-loaded mechanism, which prevents exposure of the adhesive tape until after the UAS lands on the sample area.

Figure 2. Unmanned aircraft system with adhesive tape sampling payload.

3.3 ACORNS Chemical Detection and Vapor Collection Module

The Array Configured of Remote Network Sensors (ACORNS) chemical detection and vapor collection module (Figure 3) was developed in a parallel effort to the UAS and integrated on the UAS.* This module incorporates a miniaturized point detector based on the Joint Chemical Agent Detector along with vapor collection sorbent tubes. The stacking, modular ACORNS design enables capabilities to be quickly and easily added, removed, or changed to meet mission requirements.

* Colgan, M.A.; Muzii, R.E. *Array Configurable of Remote Network Sensors (ACORNS) Final Report*; ECBC-TR-1364; U.S. Army Edgewood Chemical Biological Center: Aberdeen Proving Ground, 2016; UNCLASSIFIED Report.

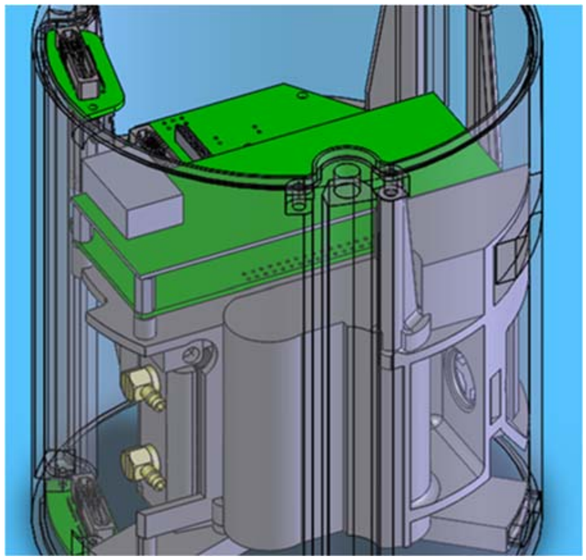

Figure 3. Cutaway view of the ACORNS chemical detection and vapor collection module.

4. RESULTS

Several demonstrations of the collection payload were conducted. The re-purposed weather-accommodating structure for hovering, remote sensing, and aerial combined knowledge (WASHRACK) has canvas walls and a roof with open mesh ends, which enabled quick evaluation of the developmental systems adjacent to the development and integration facilities.

The chemical detection and vapor collection module was attached to a powered UAS (Figure 4), and real-time detection data were received on a laptop application. For these demonstrations, the UAS was not in flight but was powered with its propellers engaged in the WASHRACK.

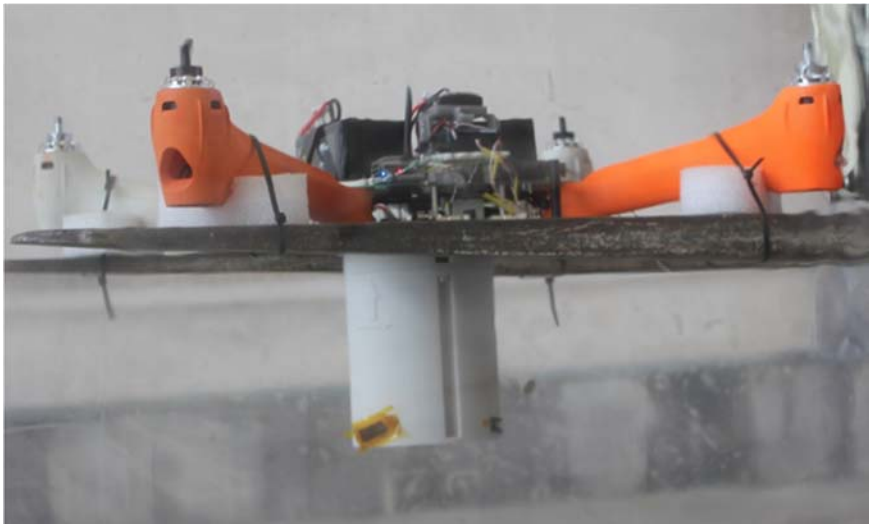

Figure 4. Testing of the ACORNS chemical detection and vapor collection module.

5. CONCLUSIONS

The execution of this effort provided a demonstration of near-term unmanned aircraft systems and payload modules that can significantly accelerate persistent standoff detection of chemical threats at sub-acute concentrations. The relatively low cost of the described product can enable broad adoption within the military. Individual Warfighters would be able to carry a personal aerial sensor platform, and the modular approach of the system ensures that it can be upgraded with the latest flight components and sensor materials.

ACRONYMS AND ABBREVIATIONS

ACORNS	Array Configured of Remote Network Sensors
CBRNE	chemical, biological, radiological, nuclear, and explosive
ECBC	U.S. Army Edgewood Chemical Biological Center
UAS	unmanned aircraft system
VTOL	vertical takeoff and landing
WASHRACK	Weather-accommodating structure for hovering, remote sensing, and aerial combined knowledge

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